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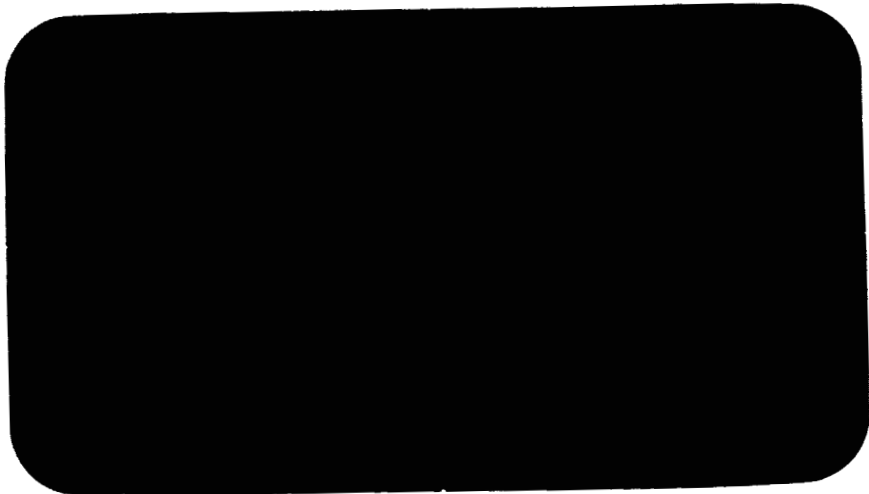
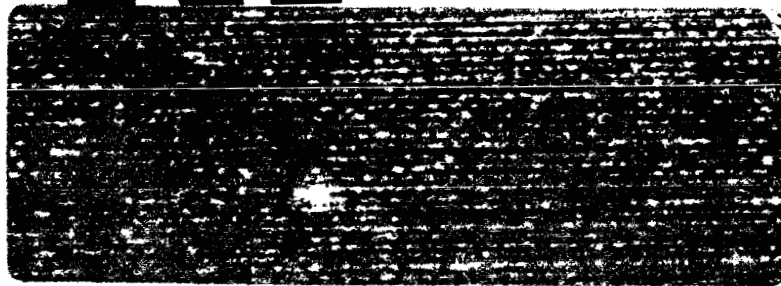
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GPO PRICE \$ _____

OTS PRICE(S) \$ _____

Hard copy (HC) 1.00

Microfiche (MF) 50



FACILITY FORM 602

N65 17534

(ACCESSION NUMBER)

9

(PAGES)

60853

(NASA CR OR TRS OR AD NUMBER)

(THRU)

1

(CODE)

32

(CATEGORY)

IIT Research Institute Project M6046
Application of Prestressed Segmented
Brittle Materials in Aerospace Structure

Seventh Quarterly Report

February 15, 1965



IIT Research Institute
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312/225-9600

February 15, 1965

Grant and Research Contracts Division
Office of Space Science and Applications
National Aeronautics and Space Administration
Washington, D. C. 20546

M6046

Attention: Miss Winnie M. Morgan

Subject: NASA Contract No. NASr-65(04)
Seventh Quarterly Status Report IITRI Project M6046
"Application of Prestressed Segmented Brittle
Materials in Aerospace Structure."

Gentlemen:

This is the Seventh Quarterly Progress Report covering the period November 1, 1964 to January 31, 1965. During this period progress was made in many areas and this report will be a synopsis of this progress.

I. ANALYTICAL STUDY OF PRESTRESSED-
SEGMENTED BEHAVIOR

Under the original contract it was observed that the initial slope of the load-deflection curve, Fig. 1-a, could not be predicted. However, when the moment of inertia was reduced the necessary percentage to match up the initial slope, the rest of the curve agreed remarkably well with experiment. Thus the current effort is to try to predict the effective moment of inertia from an effective cross sectional area found from a column load-deflection curve. Our initial efforts are directed towards understanding column behavior. The problem is basically statistical and concerns the effects of column length and column cross sectional area on the distribution of effective cross sectional area. One approach which is currently being pursued involves assuming a density distribution (say rectangular) for the effective cross sectional area of one segment and then using probability theory, predicts the effective area of a column of two segments on up to n segments. Another approach involves the application of the distribution of the means of samples of size n .

The load deflection curve of a prestressed-segmented bending member, Fig. 1-a, is strongly suggestive of an elastic-perfectly plastic bending member. A promising study of the application of the considerable literature on limit analysis of structures is currently in progress. It is probable that many existing theorems and analysis may be used directly to predict ultimate loads for prestressed-segmented bending members.

II. EXPERIMENTAL STUDY OF PRESTRESSED-SEGMENTED BEHAVIOR

Circular glass segments are being manufactured from one sheet of glass to insure that, statistically, all of the interfaces come from the same population. There are five sizes 1/2" to 3" in diameter. Columns will be assembled from these segments and subsequently tested to determine their effective areas. In this way the statistical distributions as functions of length and area will be determined experimentally.

The loading and instrumentation fixtures and other apparatus have been debugged and checked out for the determination of the terminal couple-end rotation curve of the TiC prestressed-segmented beam, Fig. 2. The accuracy of the system was first verified by substituting a tool steel beam of known modulus, for the TiC beam and going through the complete test and analysis. Results for the TiC beam are now being analyzed and converted into effective moments of inertia. Subsequently the beam will be tested as a column to determine the effective area and an attempt will be made to correlate the effective area to the effective moment of inertia for each value of the axial load.

Preliminary results from the "backbone" segmented column study suggest that there is no significant difference in the strength-to-weight ratio compared to the cylindrical segmented column. It was hoped that the backbone geometry would introduce a state of compression which would more than offset the tensile stresses generated by the imperfect contact between segments. In the testing of the cylindrical segmented columns an unexpected phenomena manifested itself. In a significant number of tests longitudinal cracks developed which seem to propagate across the interface between segments as in Fig. 3.

III. ANALYTICAL STUDY OF PRESTRESSED-MONOLITHIC BEHAVIOR

By combining the techniques developed for the analysis of prestressed-segmented behavior with the existing tools and techniques from the field of statistical fracture, a great deal can be easily effected towards understanding and predicting prestressed-monolithic behavior, Fig. 1-b. Using the methods of statistical fracture theory the statistical distribution of the initial fracture, Fig. 1-b, may be predicted. Cracks are initiated on the tension side of a bending member. If we assume that the cracks cannot penetrate into the compression side, then the partially cracked prestressed-monolithic bending member behaves to a large extent as if it were segmented.

Thus it appears reasonable that the "segmented" theory can be used to predict a lower bound as in Fig. 1-b. The reason why the "segmented" theory should be a lower bound is that it assumes an infinite number of cracks and any monolithic member should crack in only a finite number of places. In general, prestressing a monolithic brittle bending member effects an increase in the load carrying capacity and prevents catastrophic failures.

IV. EXPERIMENTAL STUDY OF PRESTRESSED-MONOLITHIC BEHAVIOR

Hydrostone plaster was selected as the model material because of its low cost, availability, and IITRI's extensive experience with it. Two hundred small beams $1\frac{1}{2}$ " x $1\frac{1}{2}$ " x 10", Fig. 4, are being tested to determine the statistical parameters of the material. Several computer programs are available to aid in the determinization of the statistical parameters. About 150 large beams 2.5" x 2.5" x 48", Fig. 4, are being tested unprestressed with about 100 others to be prestressed and tested. A loading fixture was developed especially for these beams and the prestressing fixtures are now being completed. About 150 plates $5\frac{1}{8}$ " thick x 15" diameter, Fig. 5, are currently being tested without prestressing; about 100 others will be prestressed and then tested. The plates are simply supported and loaded in the center. The unprestressed plates and the required fixtures were developed on a brittle design program for the U. S. Air Force.

Respectfully submitted,

IIT RESEARCH INSTITUTE

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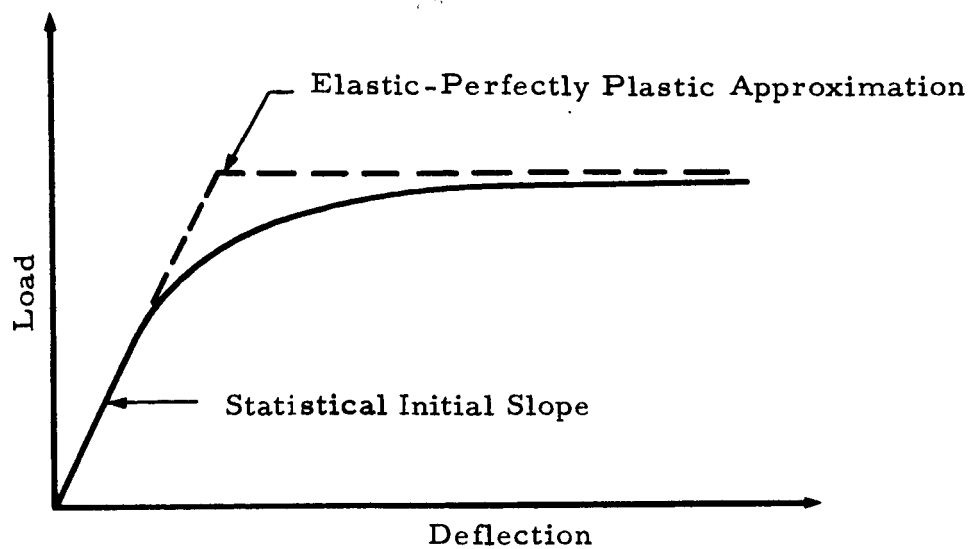


Fig. 1-a PRESTRESSED-SEGMENTED
BENDING BEHAVIOR

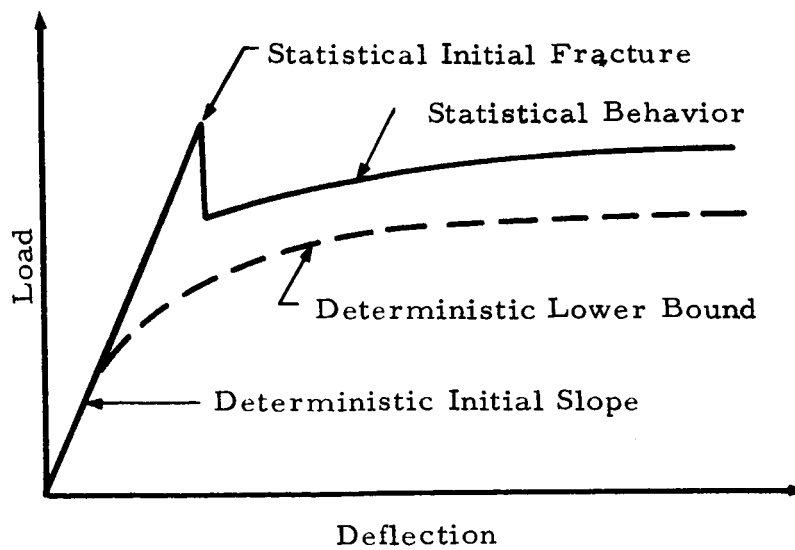


Fig. 1-b PRESTRESSED-MONOLITHIC
BENDING BEHAVIOR

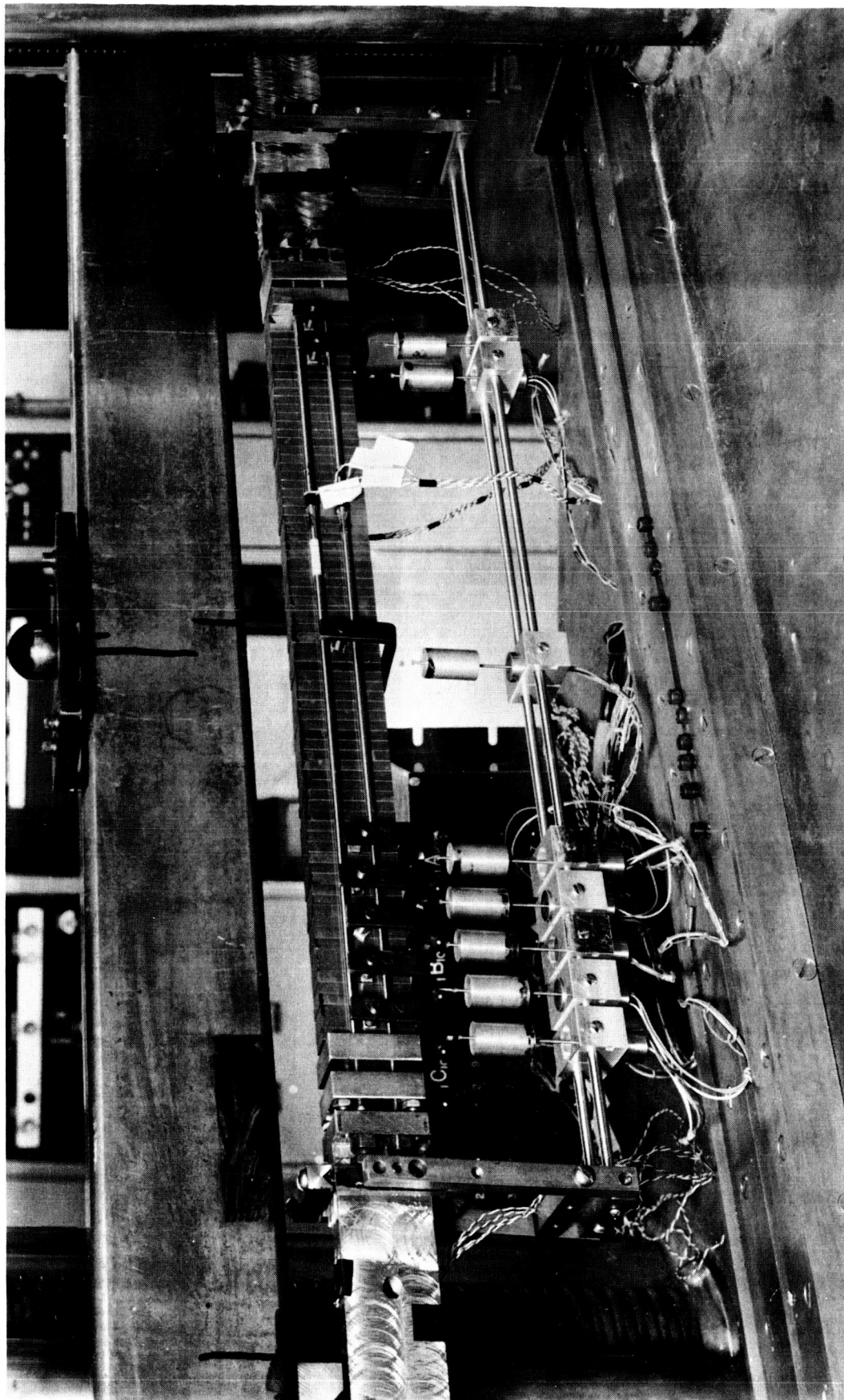


Fig. 2 PRESTRESSED-SEGMENTED TiC BEAM TEST SET-UP

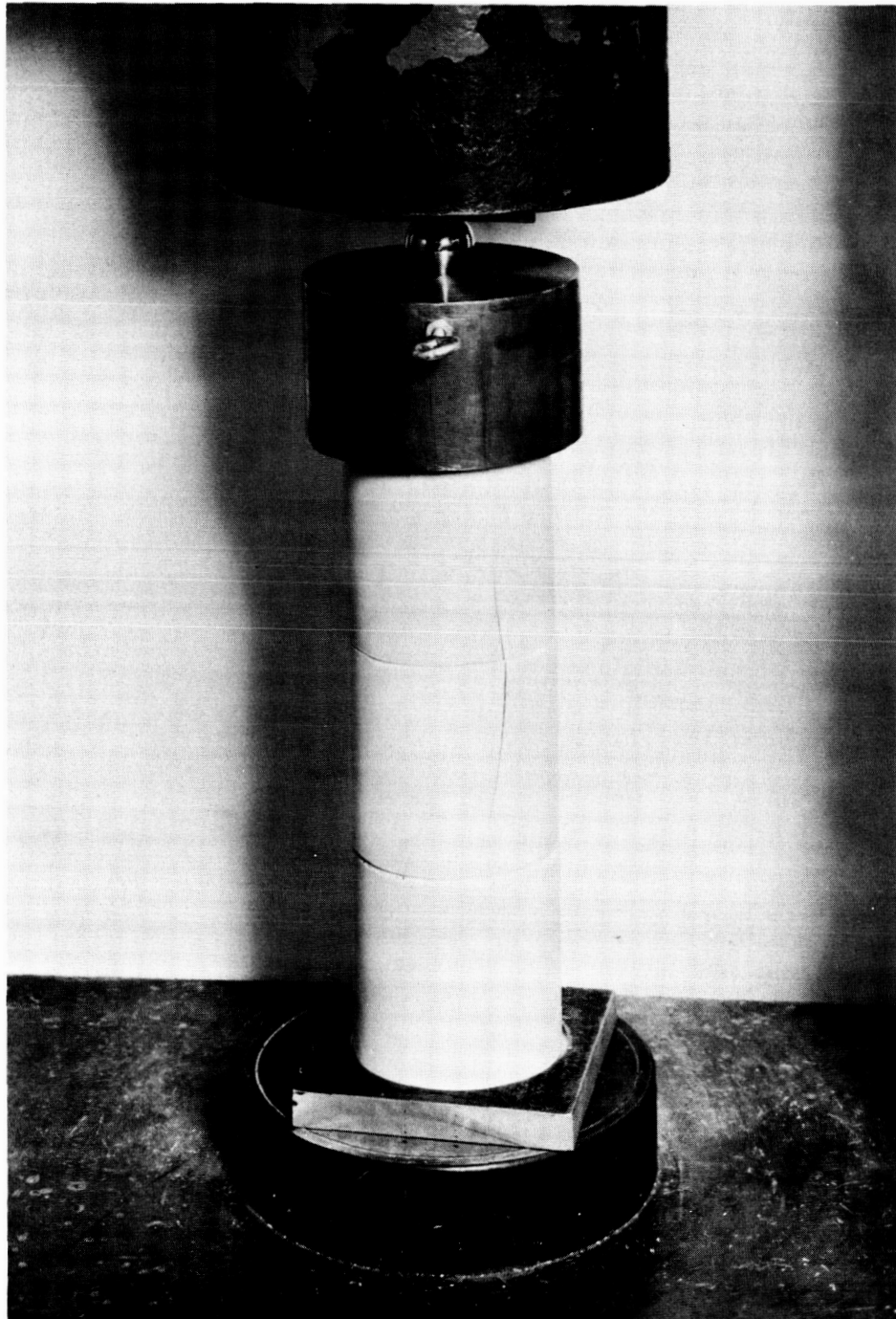


Fig. 3 CYLINDRICAL SEGMENTED COLUMN WITH LONGITUDINAL
CRACK ACROSS AN INTERFACE

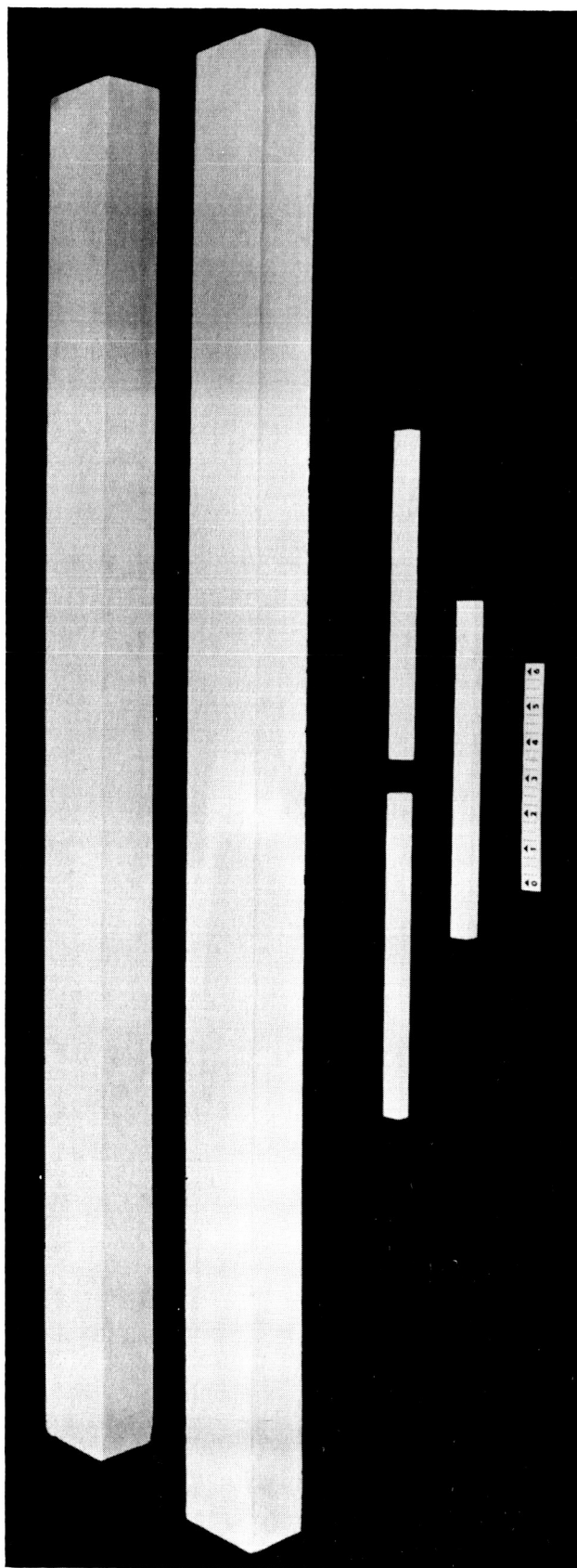


Fig. 4 LARGE AND SMALL PLASTER BEAMS

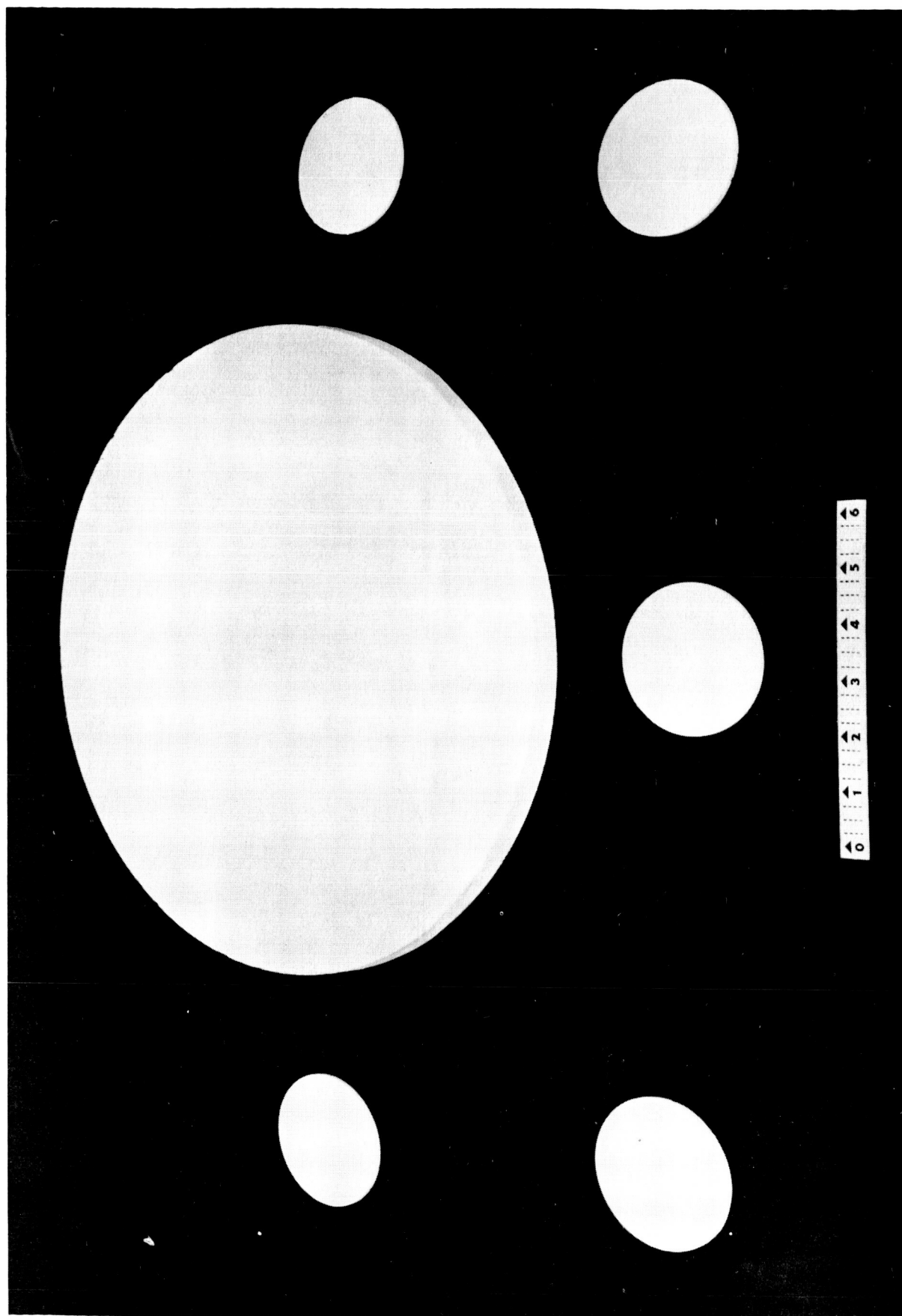


Fig. 5 LARGE AND SMALL CIRCULAR PLASTER PLATES